Smart Data SDNITS in the SKY

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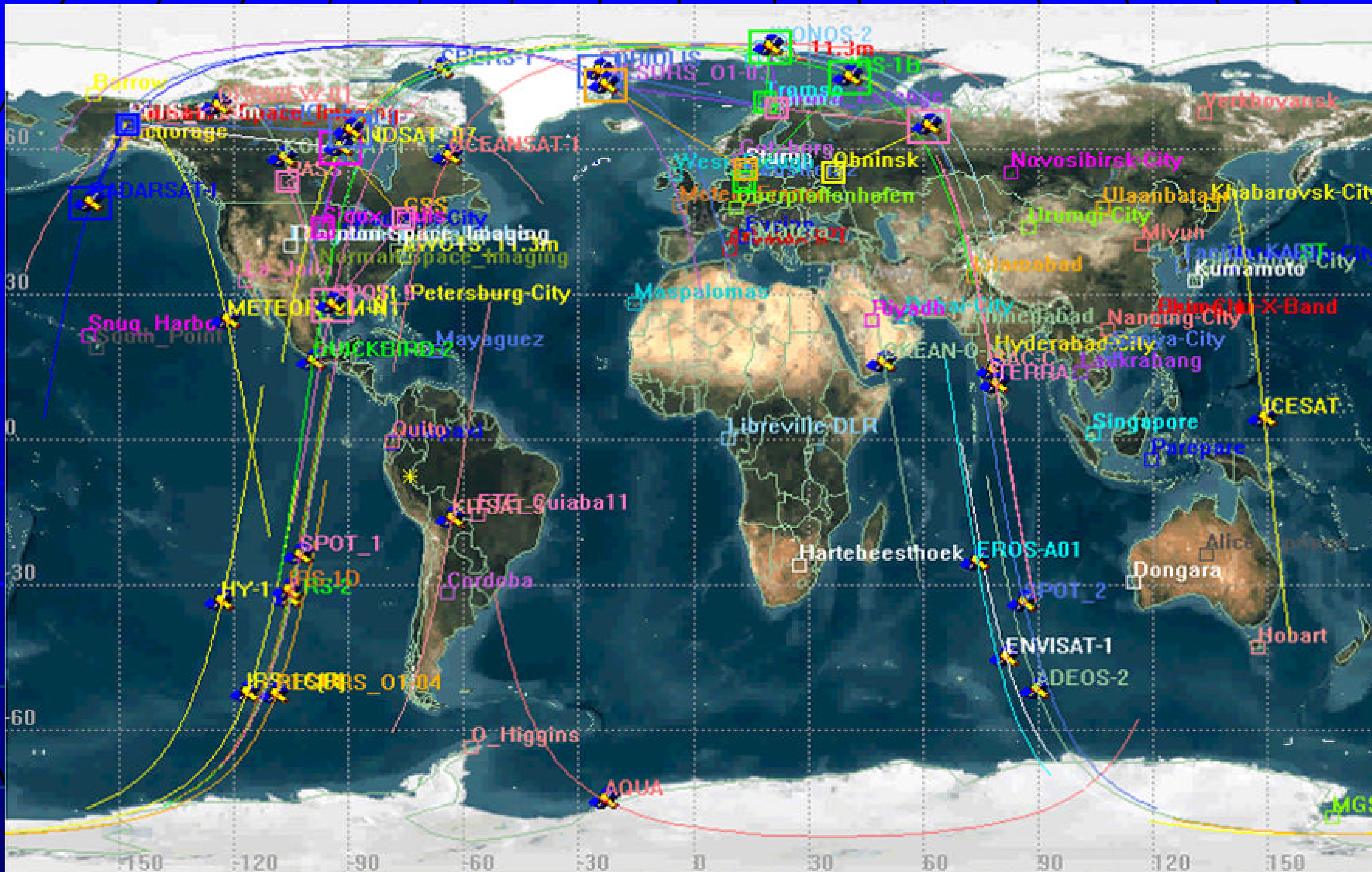
Why SDNITS?

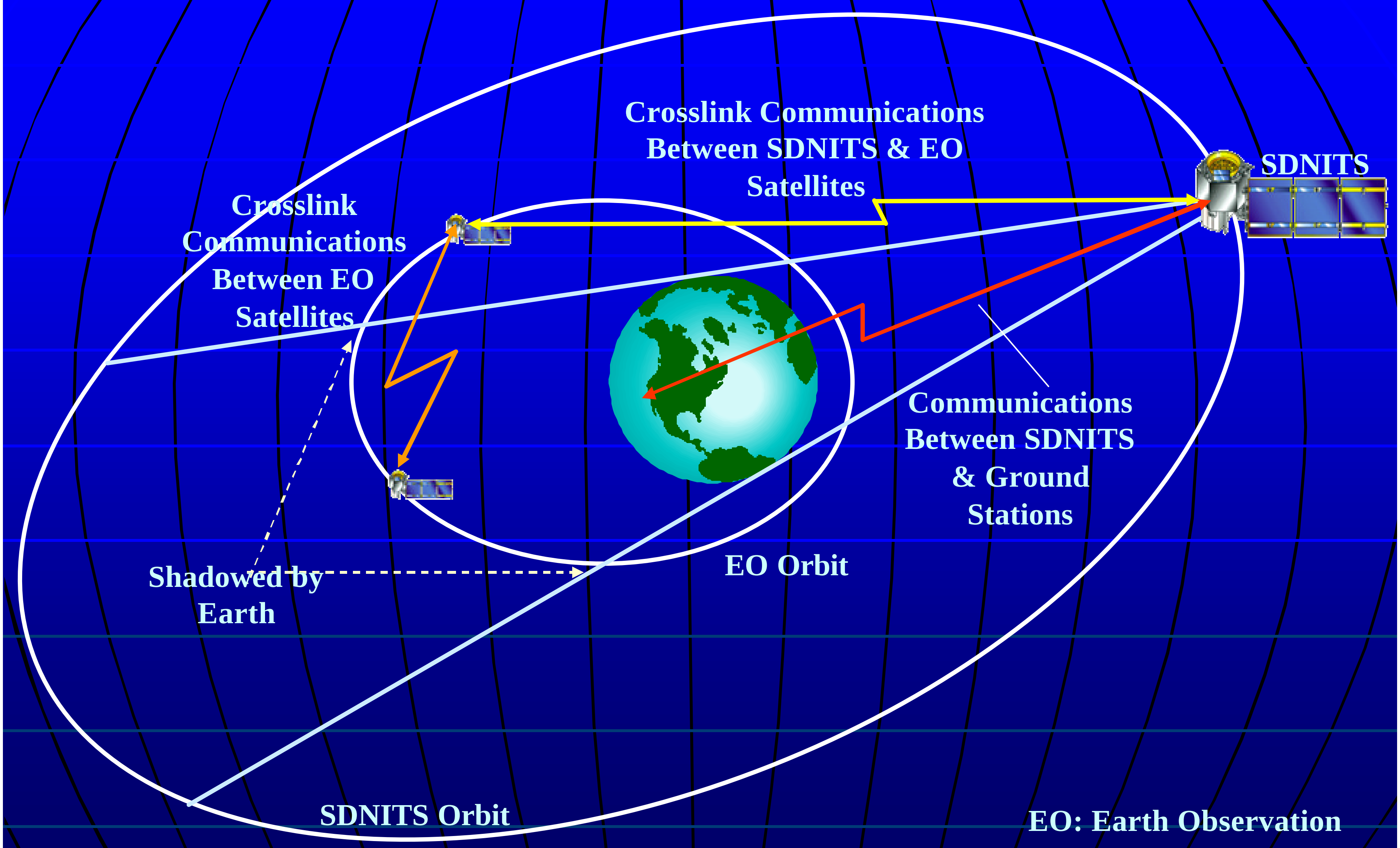
- The need for high resolution mapping of the earth's surface, more accurate atmospheric sounding data, soil moisture and vegetation mapping on the earth's surface and their seasonal variations will soar considerably.
  - Science instrument data rates will be in the range of 1 Gbps to 45 Gbps. Even with advanced compression algorithms (10:1 to 100:1) the satellite down link data rate will be in the range of 1 Gbps to 10 Gbps.
- SDNITS is designed to serve the of data transport needs of many satellites in different orbits, simultaneously transmitting to the designated destinations.

Video EESS Workshop



Courtesy of Charlene Chen and Ralph Cager, *ASRC Aerospace Corporation*

SDNITS Preliminary Concept



EO: Earth Observation

SDNITS Orbit

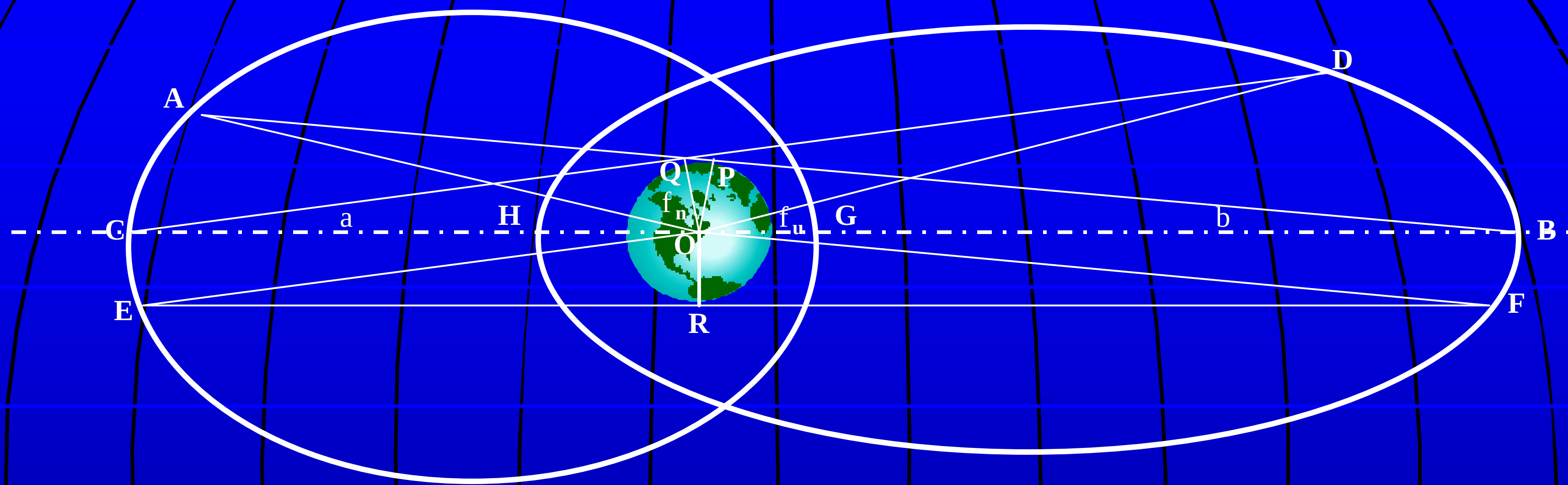
Low Earth Orbit (LEO)	Geo-Synch Earth Orbit (GEO)
There may be several consecutive User satellite orbits before the SDNITS is seen consequently the onboard storage required may be large.	The User satellite will see the SDNITS in its every orbit and has an opportunity of downloading the data. Thus the storage need is not large.
Visibility time of the SDNITS from the User satellite will be short hence a very high data rate system must be installed on the User satellites.	Visibility time of the SDNITS from the User satellite will be long hence a relatively low data rate system will be needed on the User satellites.
To make the visibility times larger, many SDNITS satellites will be required in the system making it expensive.	At most 3 SDNITS will be needed to provide almost perfect coverage for the User satellites. The cost will be held down.
Depending upon the orbits of User and SDNITS, the cross velocity between them may be high making the pointing of User antenna a difficult task resulting in loss of gain.	The cross velocities between the User satellite and the SDNITS will be lower and hence the pointing of User antenna would not be excessively difficult.
The range between the User satellite and the SDNITS will not be great and hence less onboard telecom power will be needed for transmission.	The range between the User satellite and the SDNITS will be at least equal to GEO altitude making more onboard telecom power necessary for transmission.
Easy servicing of the SDNITS and less expensive.	Servicing of the SDNITS will be expensive.

Selected SDNITS Orbit : Geo Synchronous Earth Orbit

SDNITS Analyses

- To select the orbit of the SDNITS and facilitate the design of SDNITS telecom system following orbital parameters are evaluated.
  - Compute EIRP for SDNITS and User S/C
  - Compute data volume for SDNITS
  - Compute Doppler parameters

Maximum Range Computations

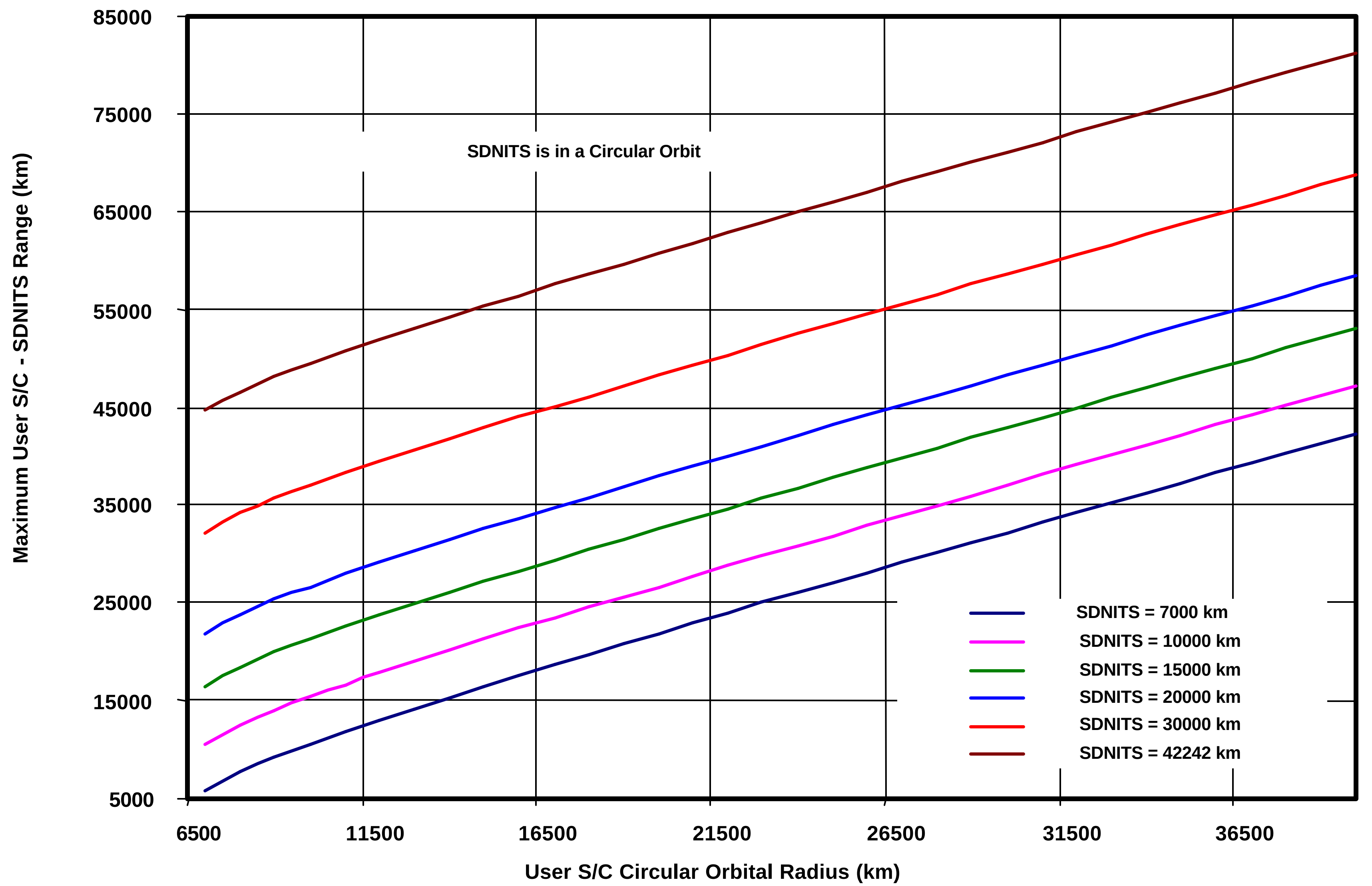


Maximum Distance Between Two Coplanar Elliptical Orbits.

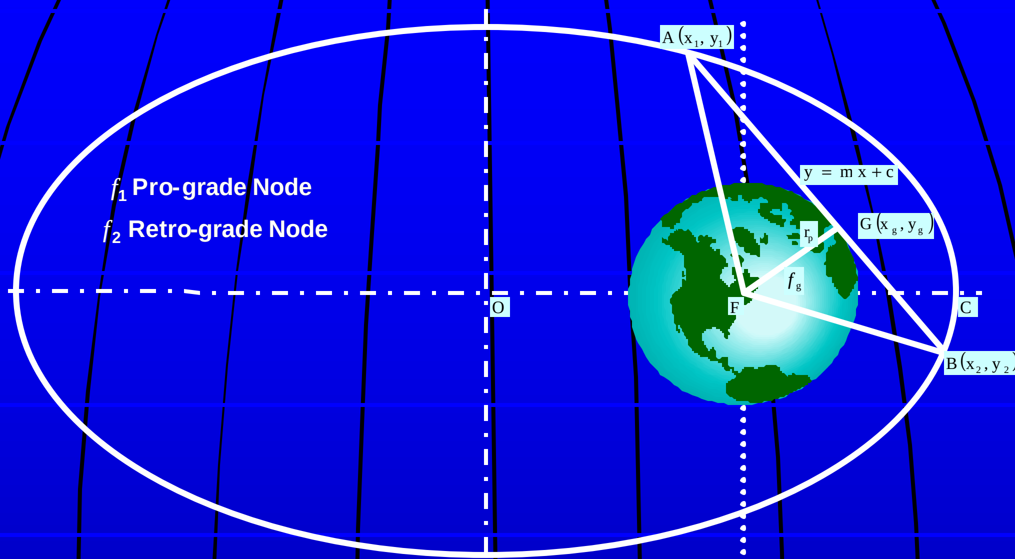
$$\text{Max Range} = \sqrt{\left[a_n(1+e_n)\right]^2 - r_p^2} + \left\{ \frac{a_n(1+e_n)^2\left\{2a_u e_u r_p^2\left(e_u^2-1\right) + a_n(1+e_n)\left[a_u^2\left(e_u^2-1\right)^2 + e_u^2 r_p^2\right]\right\}^2}{\left\{\begin{array}{l} \left[a_n^{1.5}\, a_u(1+e_n)^2\left(e_u^2-1\right)^2 + \sqrt{a_n}(1+e_n)e_u r_p^2 + e_u\sqrt{1+e_n}\sqrt{e_u^2-1} \right. \\ \left. \left[\left\{\left[a_n(1+e_n)\right]^2 - r_p^2\right\}\left\{2a_u e_u r_p^2 + a_n(1+e_n)\left[a_u^2\left(e_u^2-1\right) + r_p^2\right]\right\}\right]^{1/2}\right]^2 \end{array}\right\}} - r_p^2 \right\}^{1/2}$$

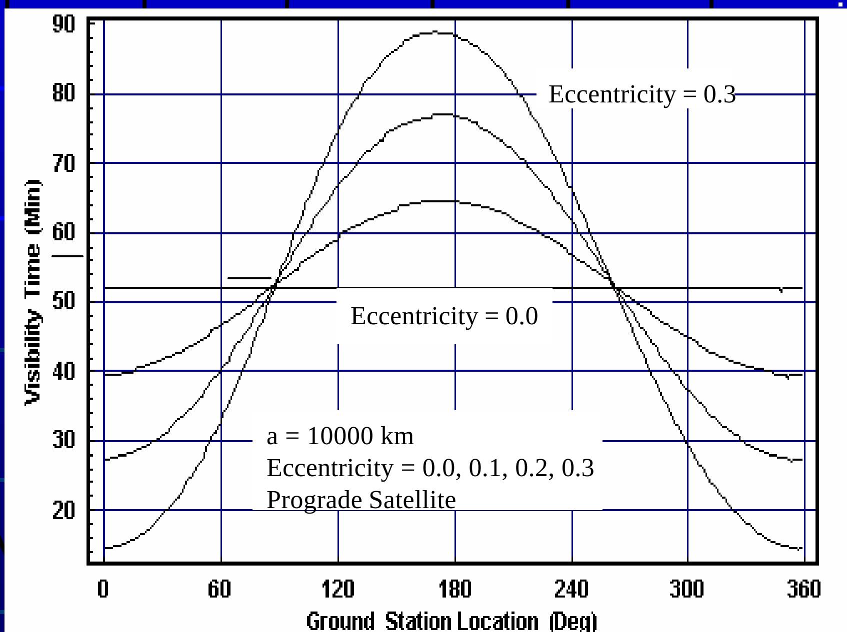
a: major axis; r: radius of planet; ε: eccentricity of orbit

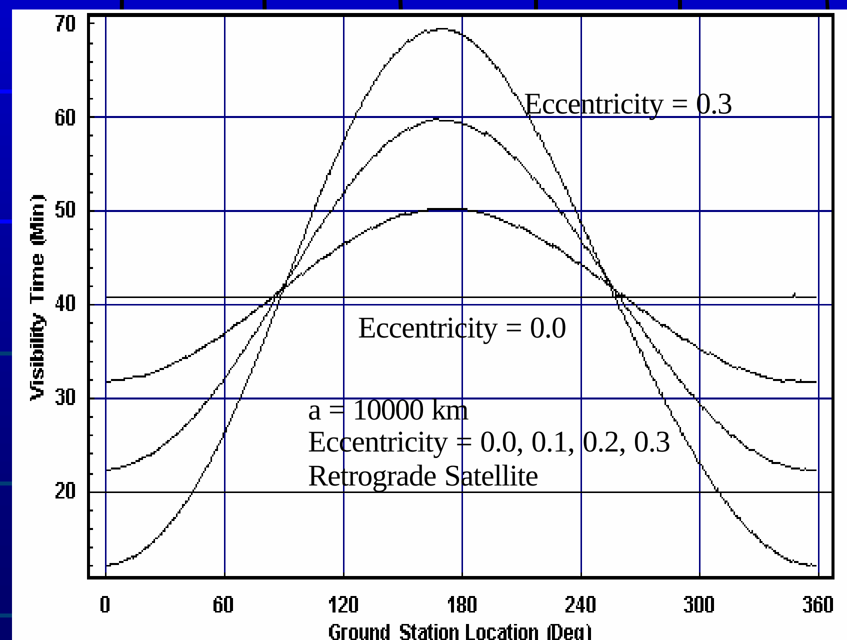
Maximum Range Results



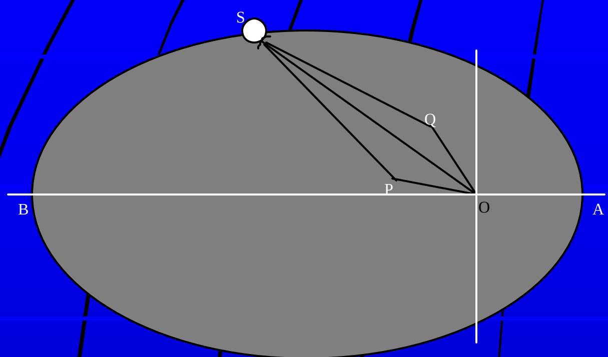
Ground Visibility



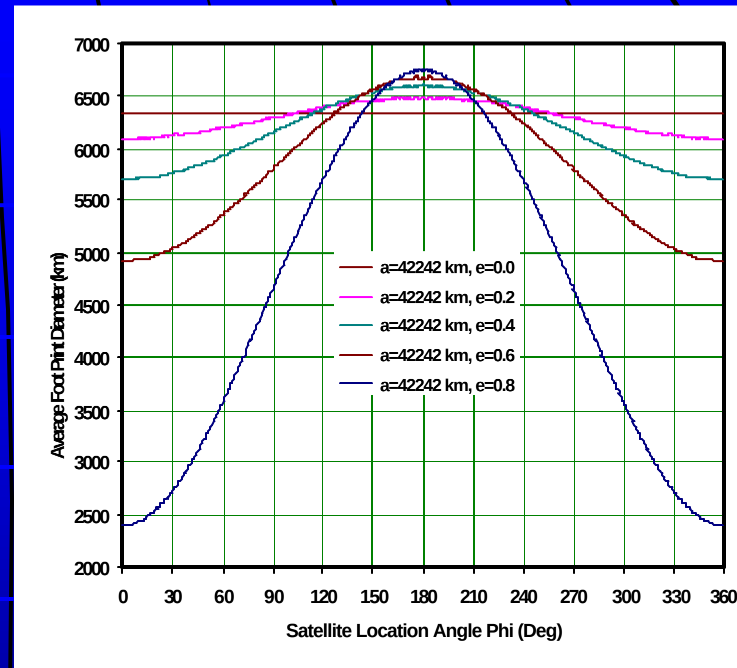


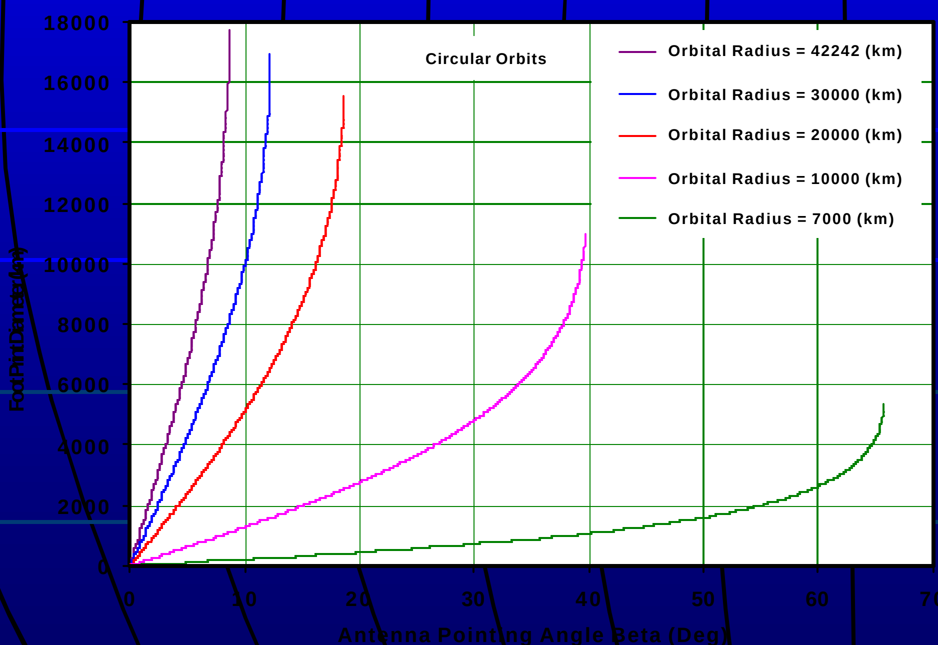


SDNITS Ground Visibility Computation

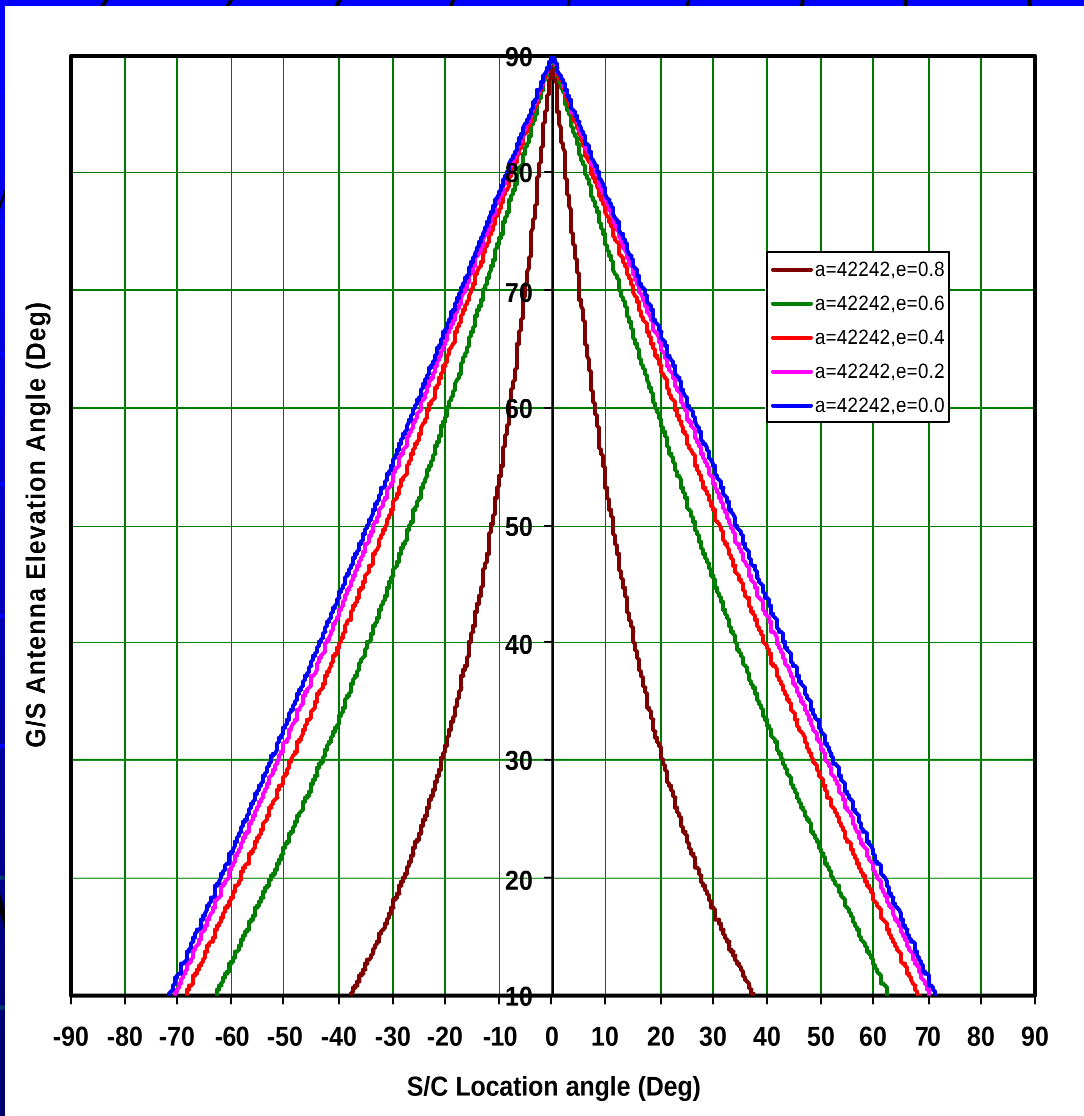


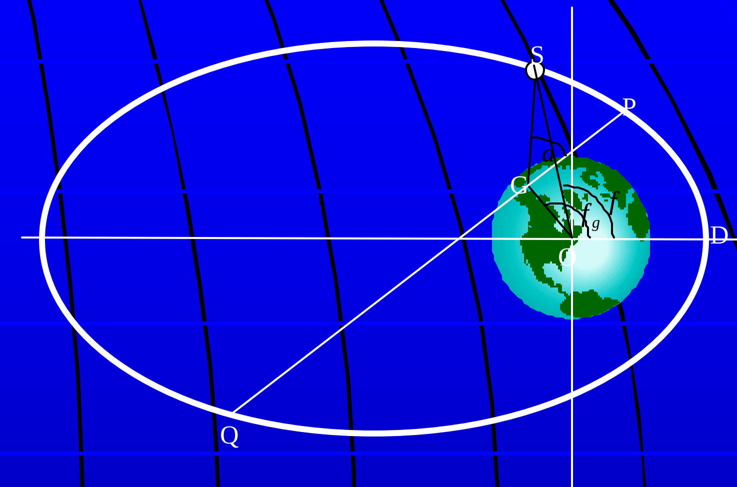
Antenna Foot Print





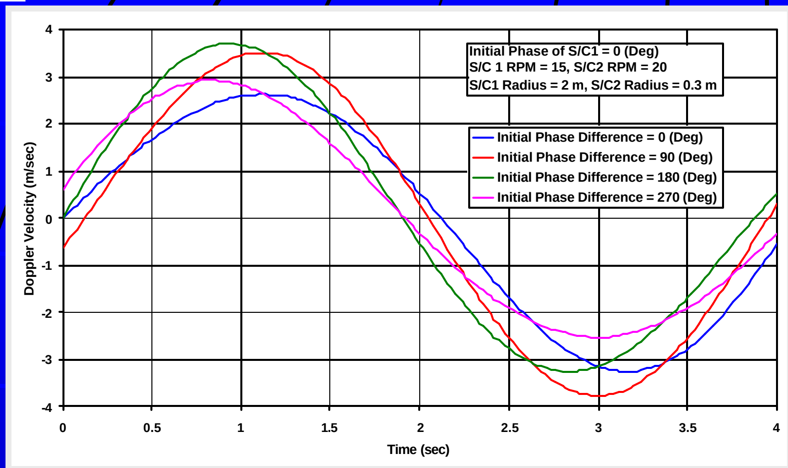
Ground Station Antenna Elevation Angle

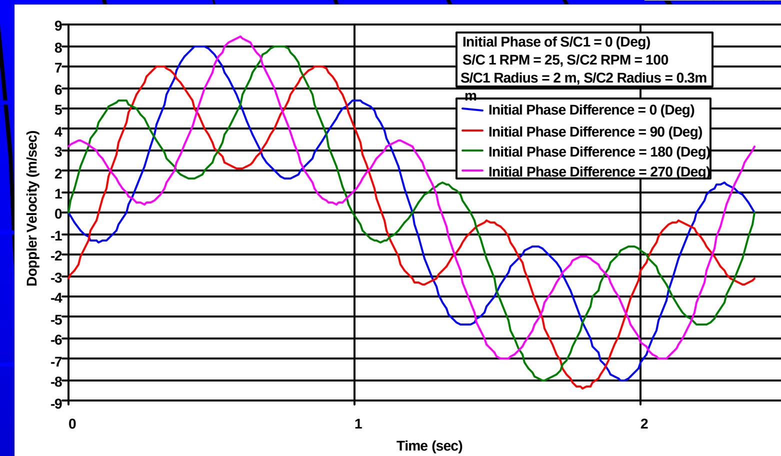




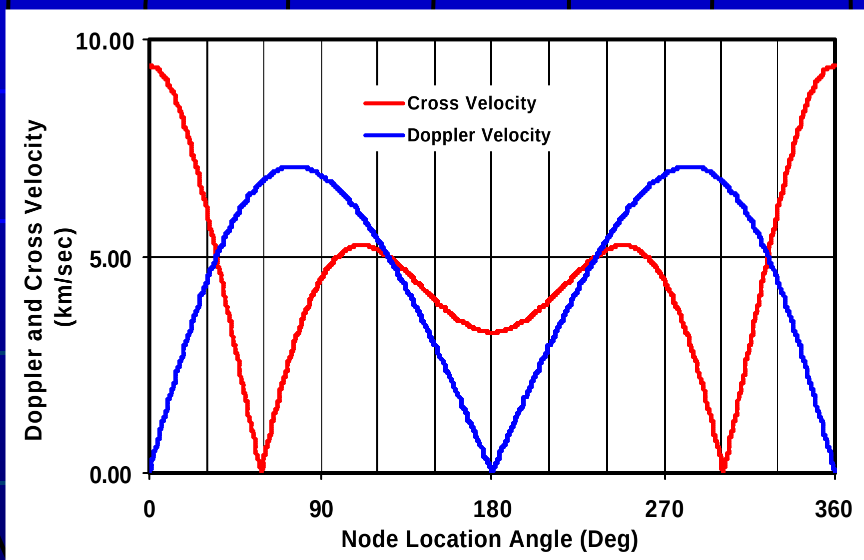
Elevation angle rate indicates Ground antenna structural stresses

Doppler Velocity

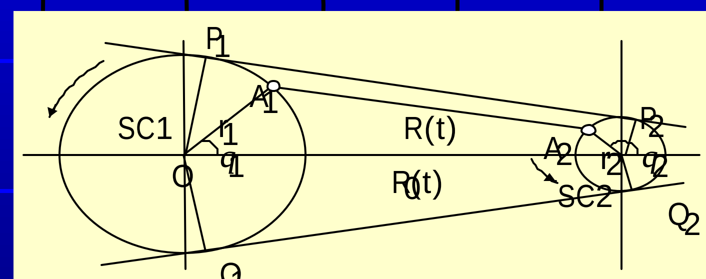




Two different cases of rotational Doppler velocity experienced by the satellites

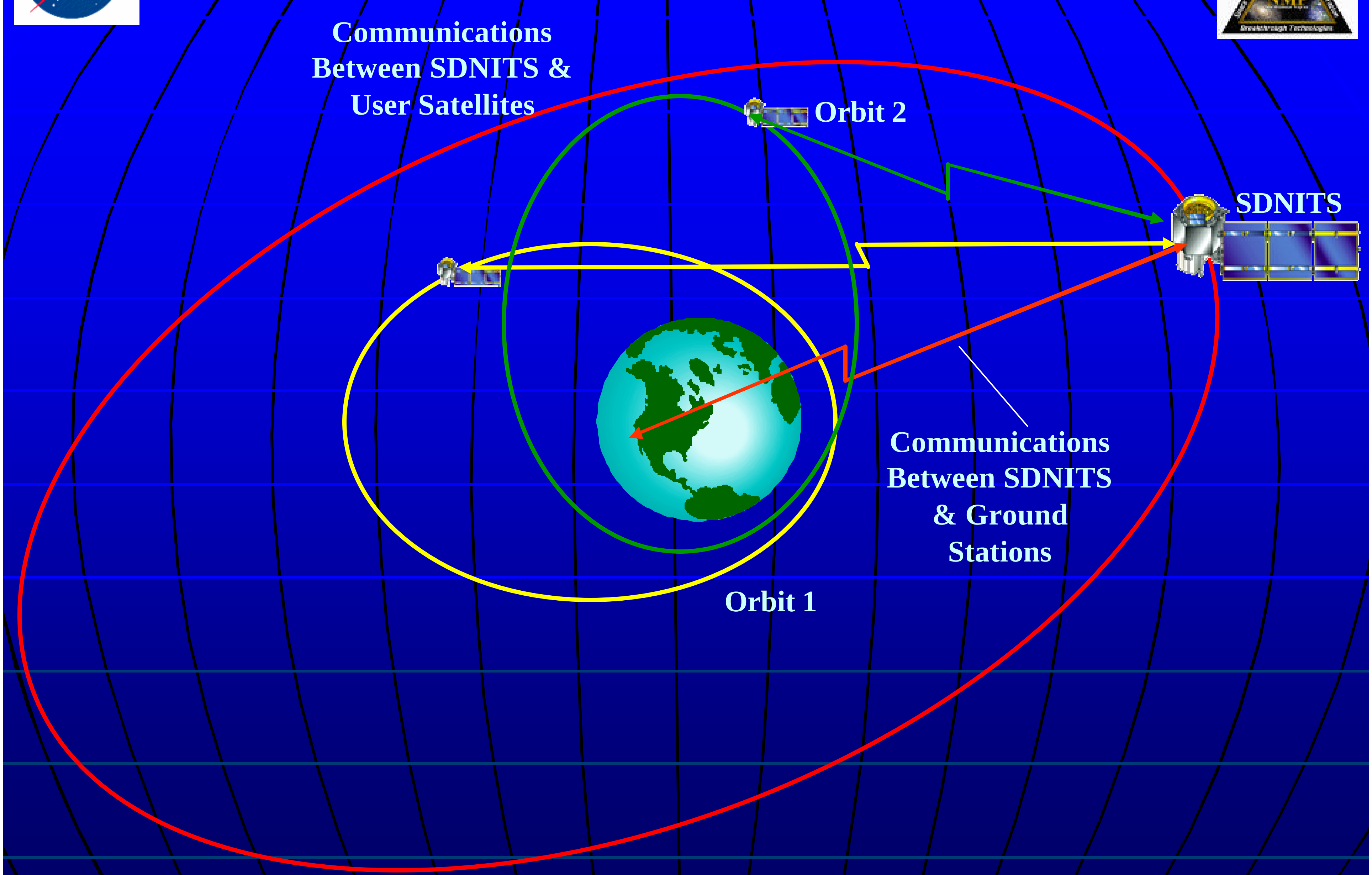


Doppler and cross velocity experienced by the satellites

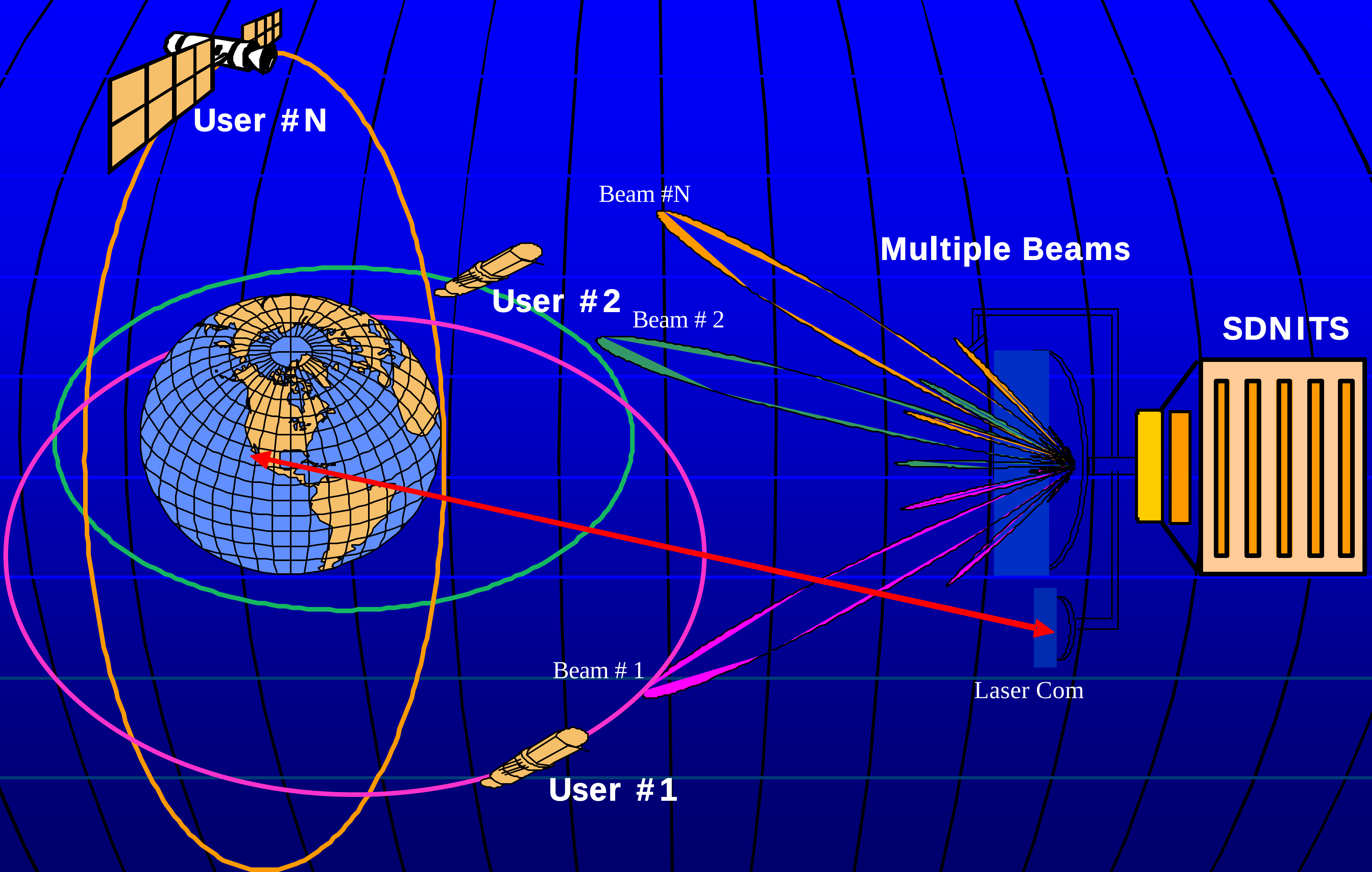


$$\frac{d[R(t)]}{dt} = \frac{\left\{ \begin{array}{l} \left[R_0(t) + \left(r_2 \,\mathrm{Cos}(q_2) - r_1 \,\mathrm{Cos}(q_1)\right)\right] \dfrac{d[R_0(t)]}{dt} \\ \quad + \left[r_1 \,\mathrm{Sin}(q_1) \dfrac{dq_1}{dt} - r_2 \,\mathrm{Sin}(q_2) \dfrac{dq_2}{dt}\right] R_0(t) - r_1 r_2 \,\mathrm{Cos}(q_1 - q_2) \end{array} \right\}}{\sqrt{R_0^2(t) + r_1^2 + r_2^2 + 2 r_2 R_0(t) \mathrm{Cos}(q_2) - 2 r_1 R_0(t) \mathrm{Cos}(q_1) - 2 r_1 r_2 \mathrm{Cos}(q_1 - q_2)}}$$

SDNITS Possible Concept

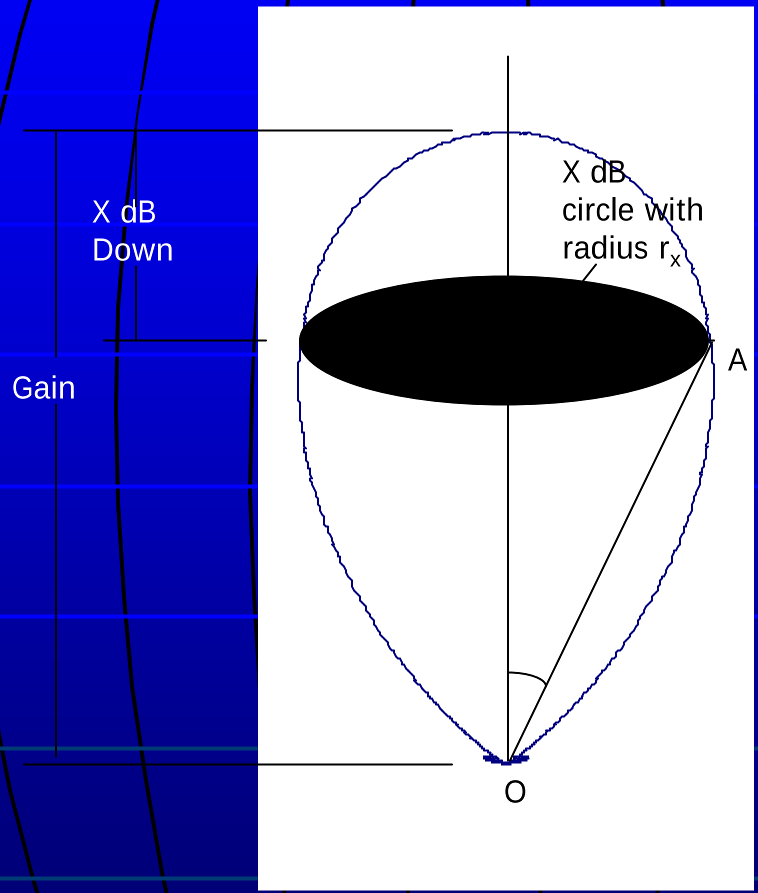


SDNITS Possible Concept

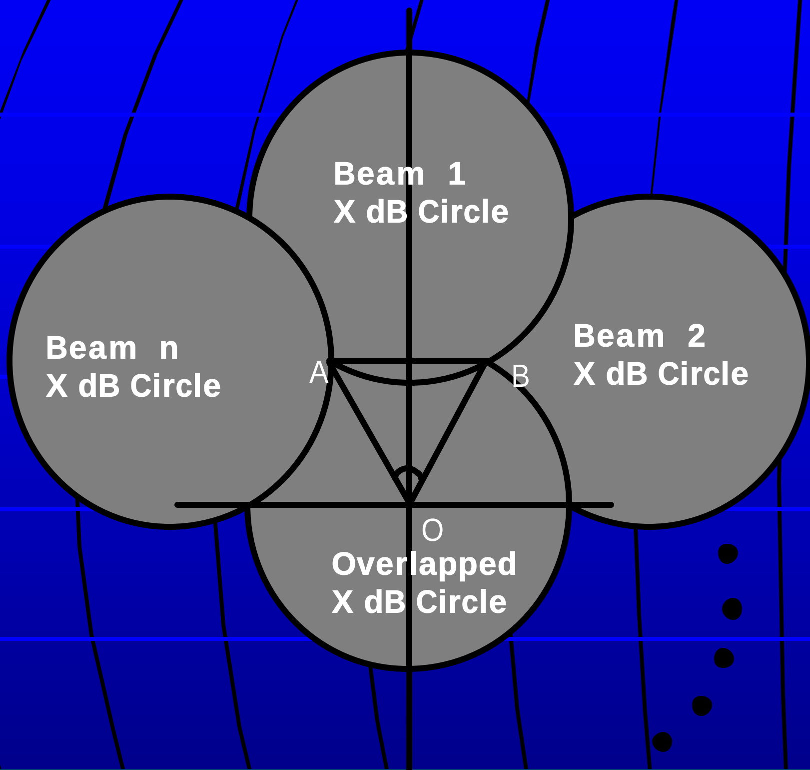


SDNITS Antenna Pattern

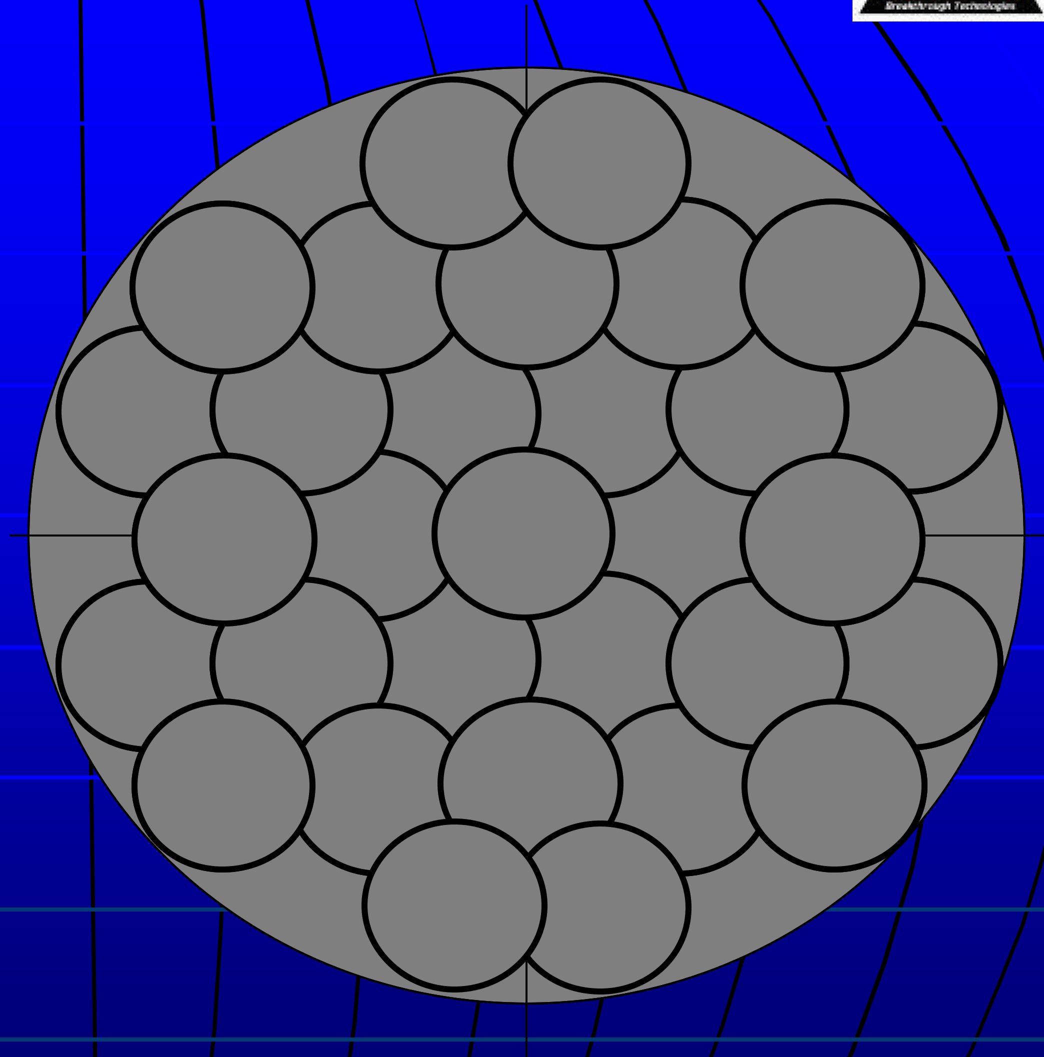
Single Lobe:



SDNITS Antenna

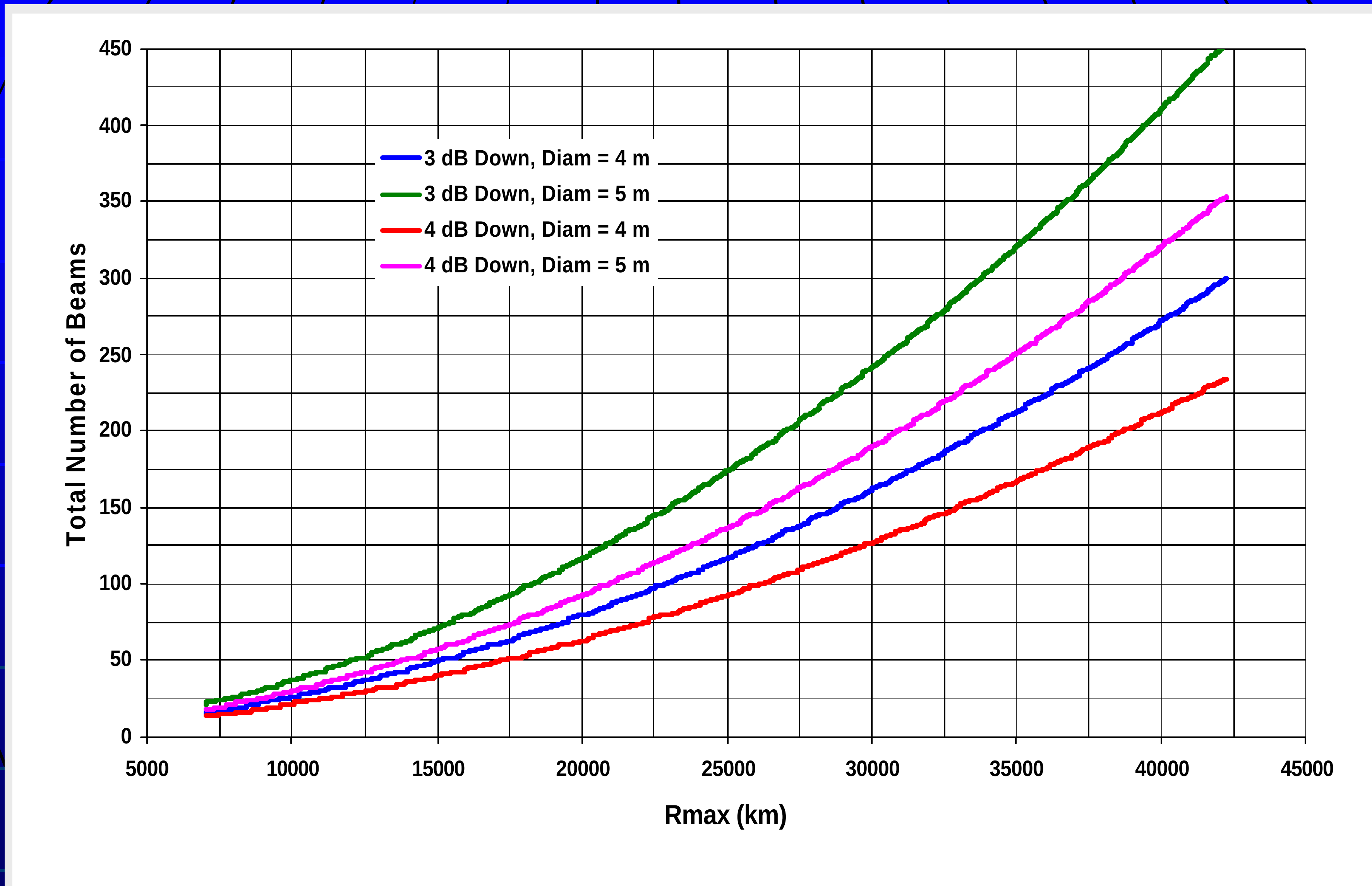


SDNITS Antenna Beam
Overlap Geometry



An Example of Beam Coverage

SDNITS Antenna Coverage



Link Budget

Desired Parameters

Desired data rate	1 Gbps
User altitude (circular orbit, eccentricity = 0)	7000 km
SDNITS altitude (circular orbit, eccentricity = 0)	42242 km (GEO)
Desired bit rate of the link	1 Gbps
Desired frequency of the link	32000 MHz (Ka-Band)

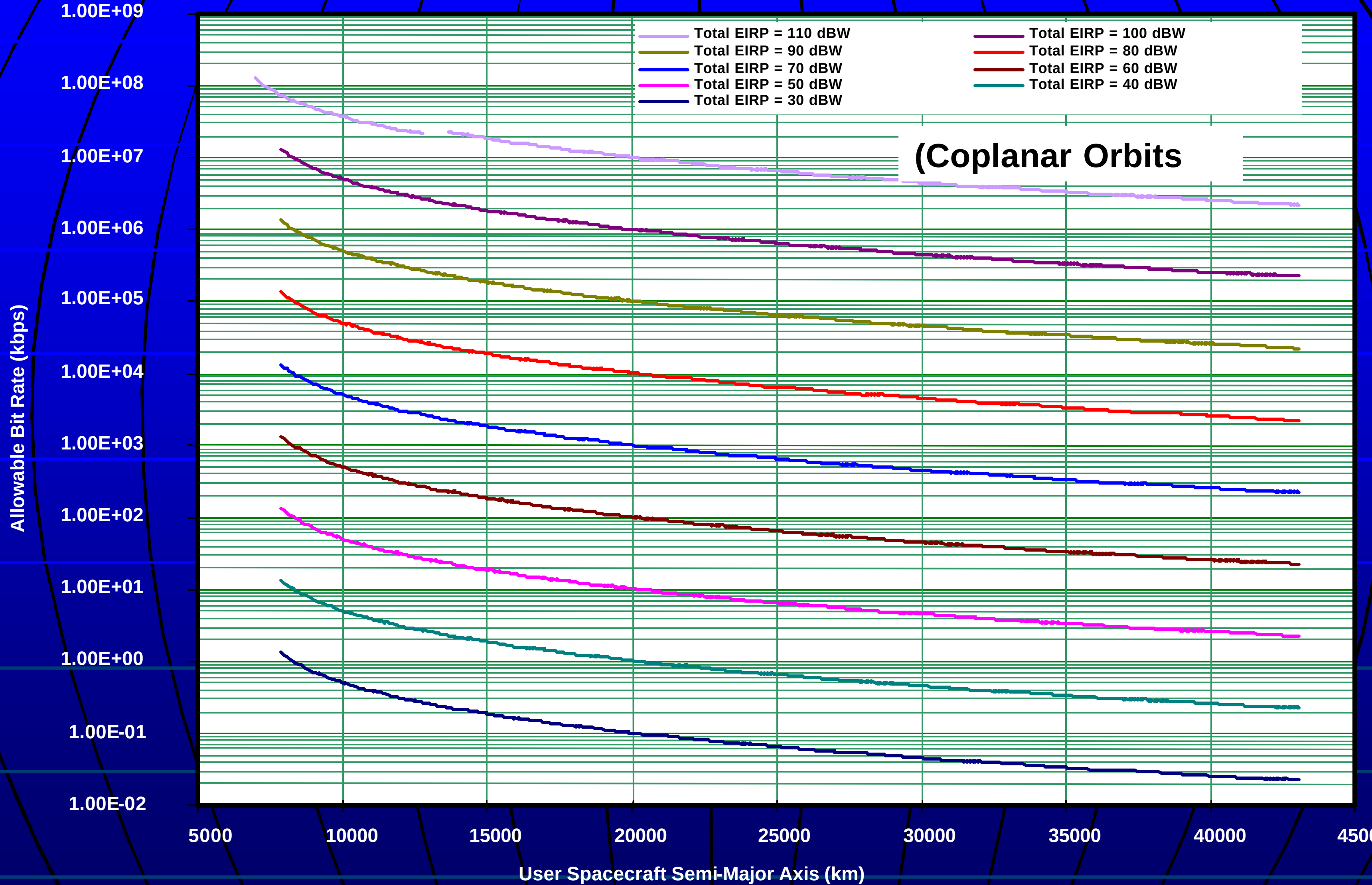
Calculated Parameters

Maximum range between SDNITS and the user satellite	44642 (km)
Total EIRP required to support the desired 1 Gbps bit rate	106 (dBW)
SDNITS antenna Gain	60 (dB)
SDNITS antenna diameter required to provide 60 dB gain	4 m
User satellite antenna EIRP required to support the desired 1 Gbps data rate	46 (dBW)
User satellite transmitted power	20 (W)
User satellite antenna diameter required to support the desired bit rate of 1 Gbps using Ka-band frequency of 32000 MHz	0.8 m

Telecom Performance

Allowable Bit Rate Vs User S/C Semi-major Axis

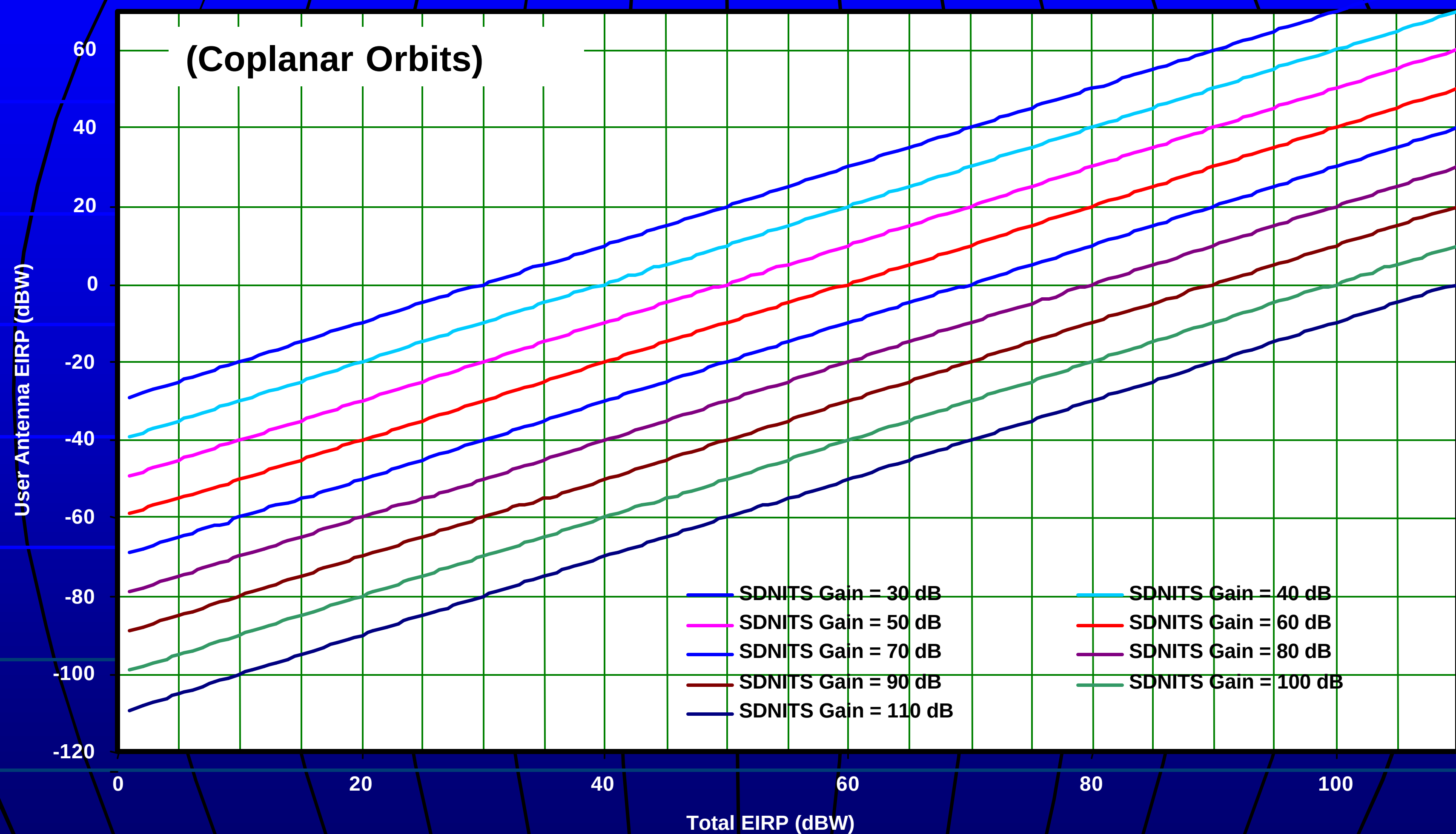
SDNITS at 42242 km, e=0.0



Telecom Performance

User Antenna EIRP as a function of Total EIRP

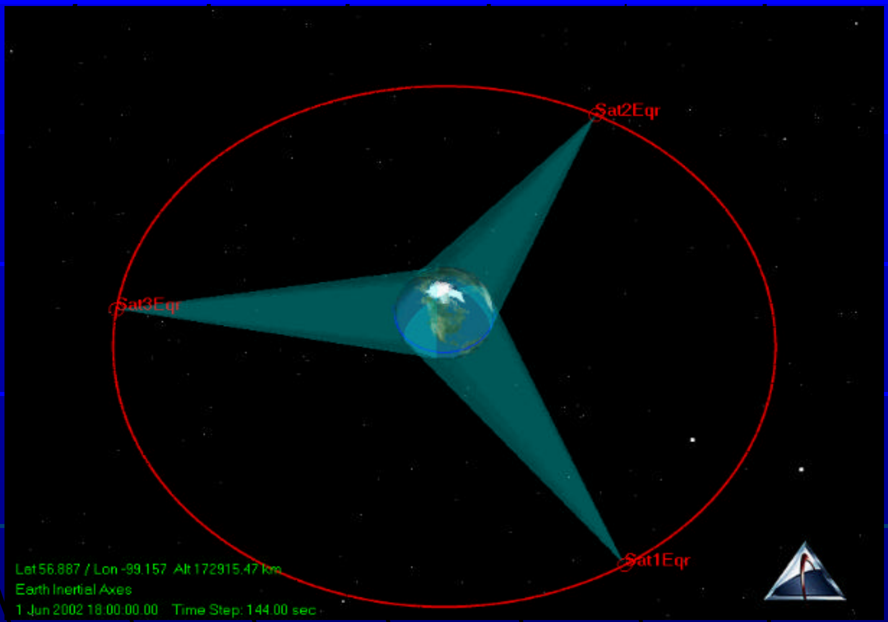
SDNITS at 42242 km, e=0.0

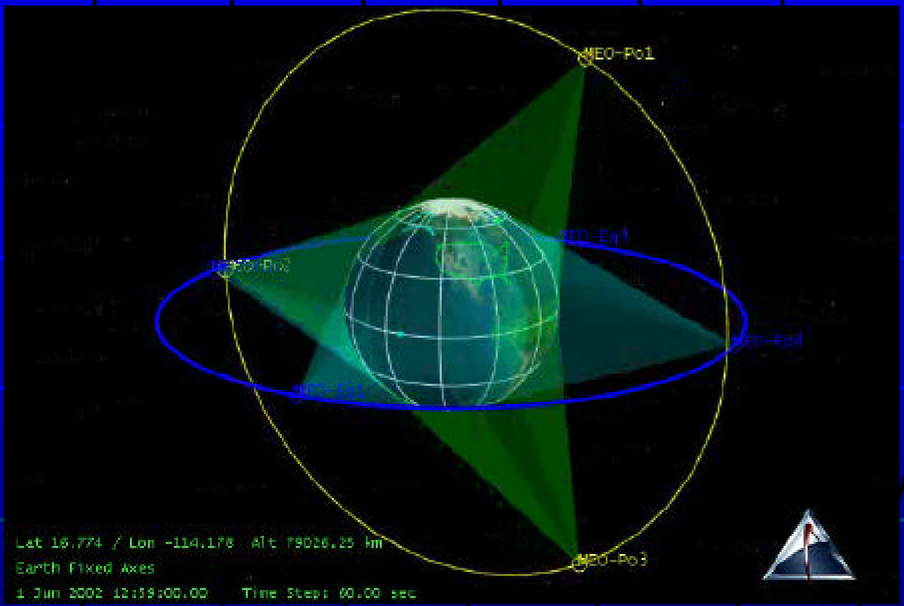


Video

Faiza Lansing and Casey Heeg

NASA/JPL





3-SDNITS system will support NASA's future missions data transport needs around the Earth.

Future Work

- Areas that need further studies:
  - Large inflatable high frequency antennas.
  - Multiple beam forming antennas.
  - Traffic Analysis
  - Protocols
  - Cloud cover, time available for transmission for laser communications link to the ground station.
  - Software simulating the entire system.